Chamonix 2014

Strategy for Run 2

(or more modestly for 2015)

J. Wenninger - BE-OP-LHC

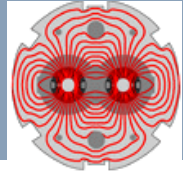
Acknowledgments:

M. Zerlauth, B. Salvachua, S. Redaelli, R. Bruce, C. Bracco, J. Jowett

V. Kain, M. Lamont, G. Papotti, A. Gorzawski, E. Metral, G. Arduini

J. Uythoven, R. Schmidt, G. Iadarola and many more

Outline



Introduction – recap RLIU Workshop

Operation strategy

Special runs

Ions

Run 2 targets – RLIU WS (1)

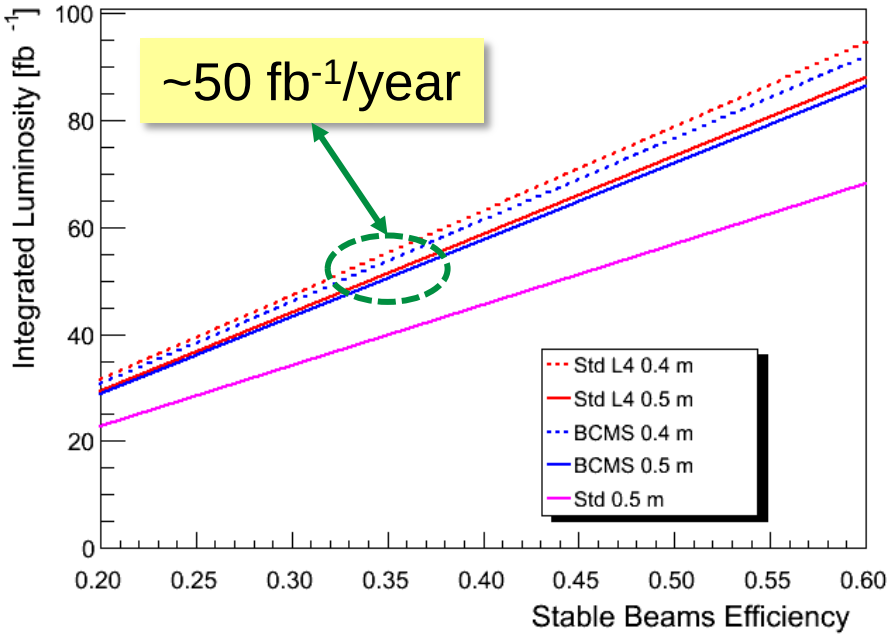
- The possible performance of future LHC runs was discussed at the RLIUP workshop in October 2013.
  - *Consider as reference target for run2.*
- Summary of the assumed beam parameters in collision (w/wo Linac4, including blow-up):

Beam type	N_{bunch} [10^{11}]	ε* [μm]	k	β* [cm]	½ Xing angle [μrad]
Standard	1.25	2.9	2740	50	190
Standard+L4	1.25	2.0	2740	40 / 50	150 / 140
BCMS (+L4)	1.25	1.65	2590	40 / 50	150 / 140

Run 2 targets – RLIU WS (2)

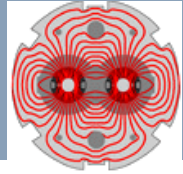
- Performance for runs of 160 days scheduled physics time.
  - *Some L leveling is required in all scenarios except std 25 ns.*
  - *Performance loss with 50 ns beams : ~50%.*

Beam	β* (m)	Leveled L (10^{34} cm^{-2}s^{-1})	Peak L (10^{34} cm^{-2}s^{-1})	Leveling time (h)
Standard	0.5	**1.65**	1.2	--
Standard+L4	0.4	**1.65**	2.1	~1.6
BCMS	0.4	**1.54**	2.2	~2.5



Remember: estimated L limit from cryogenics for triplet ~1.75×10^{34} cm^{-2}s^{-1}

What we need…

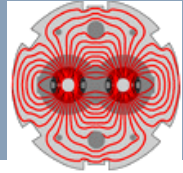


Small β^*

Bright & stable beams

Leveling

Outline



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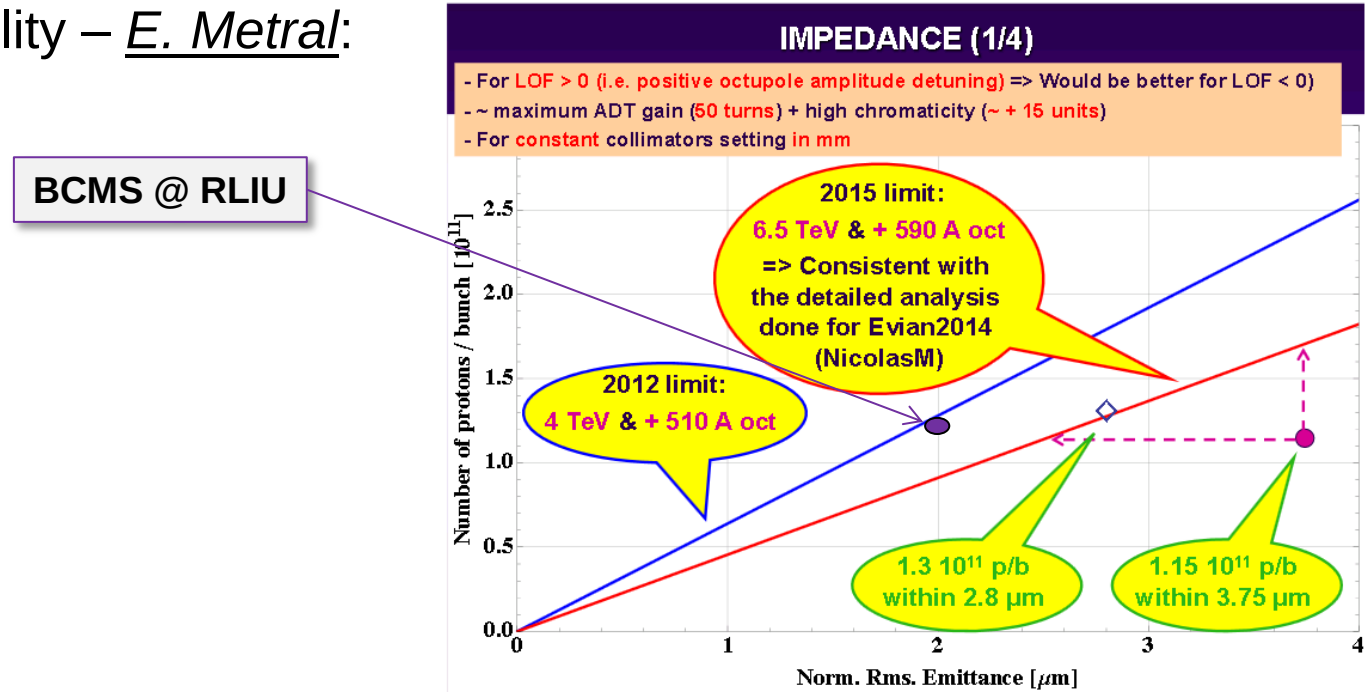
Configuration and guidelines

- Possible parameters for the startup configuration were discussed at the last Evian workshop on LHC operation (June 2014).
- Some parameters were defined at a recent LMC decisions.
  - *See also presentation by R. Bruce in the previous session.*
- The main strategy is to concentrate on 6.5 TeV and 25 ns beam to reduce complexity:
  - Relaxed β^* of 80 cm (65 cm + ~2σ margin) for the startup.
- My interpretation of the 'Guidelines' from / discussions at LPC:

Explore in 2015, produce in 2016 !

25 ns beam type

- BCMS versus standard production beam for 25 ns:
  - *Limits on injection due to MPS constraints (absorbers) – see V. Kain:*
    - **BCMS**: up to 144 bunches (1.3x10^{11} p/b, 1.3 μm).
    - **Standard beam**: up to nominal 288 bunches (1.3x10^{11} p/b, 2.6 μm).
  - *Despite stronger IBS and expected issues with beam stability, smaller beams may provide margins for blow-up – to be verified.*
  - *So far we used small emittance rather effectively.*
- Stability – *E. Metral*:



Startup performance

- Emittance choice for 25 ns beams:
  - *Standard: aligned to presentation by R. Bruce' and RLIU workshop.*
  - *BCMS: picked emittance of 2.5 μm – at Elias' stability limit (margin for blow-up from various sources).*
    - Potential tuning in injectors (tails !!).
- Extra margin from large β* assigned to MP – maintain BB separation at 11σ.

Beam type	N_{bunch} [10^{11}]	ε* [μm]	k	β* [cm]	θ [μrad]	L [$cm^{-2}s^{-1}$]	<μ>
50 ns	1.2	2.2	~1370	80	145	5.3×10^{33}	30
25 ns std	1.2	2.9*	2780			8.6×10^{33}	23
25 ns BCMS	1.2	2.5*	~2500			8.1×10^{33}	26

Bunch length 1.2 ns

(*) R. Bruce: emittances ≥ 2.7 and ≥ 1.7 μm.

Current schedule

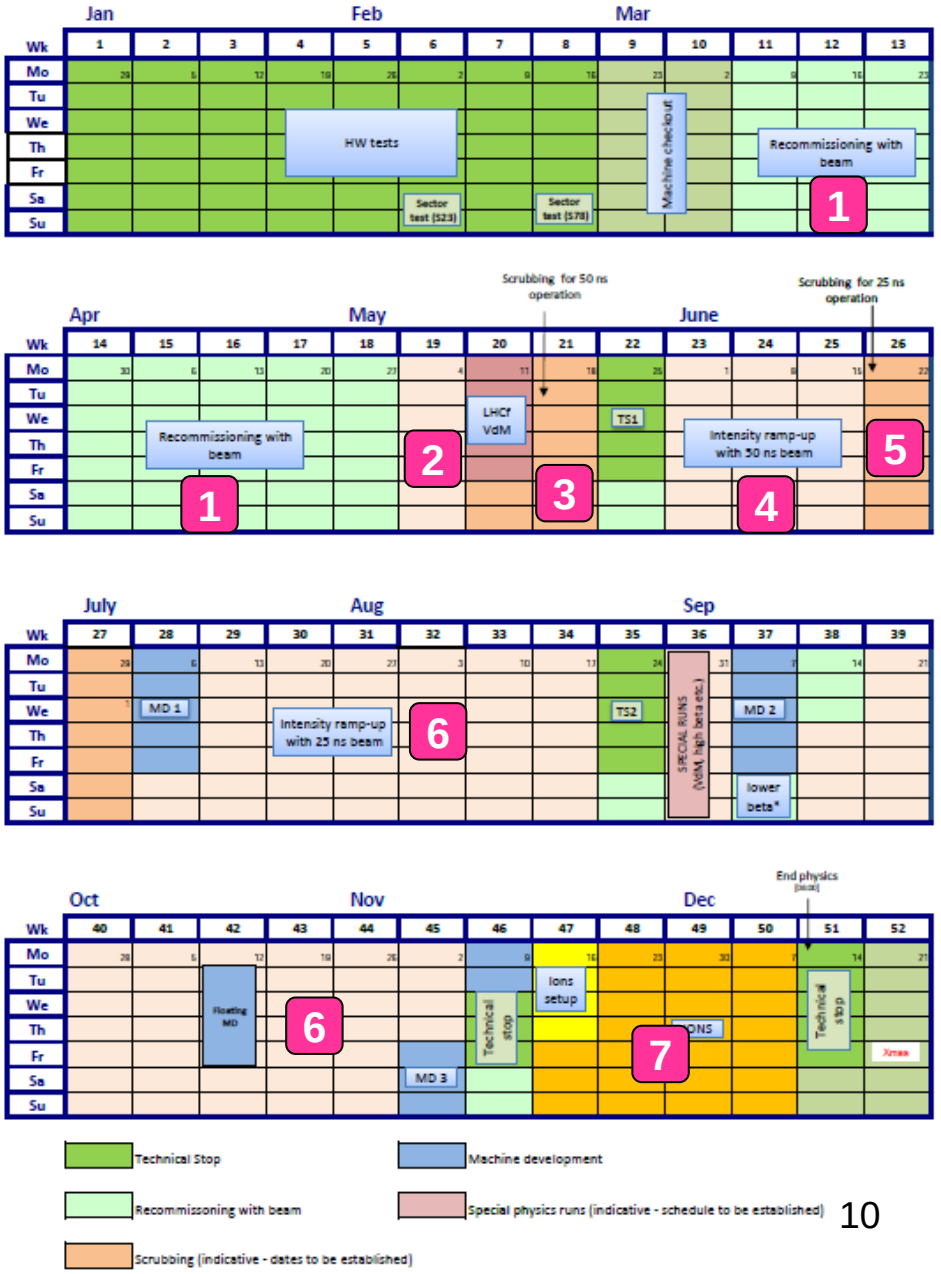
Main phases:

1. Low intensity commissioning (2 months)
2. First physics with a few isolated bunches, LHCf run
3. First scrubbing run (50 ns)
4. 50 ns operation (up to 1380 bunches/beam)

   21 days
5. 25 ns scrubbing run
6. 25 ns operation + special runs

   ~90 days

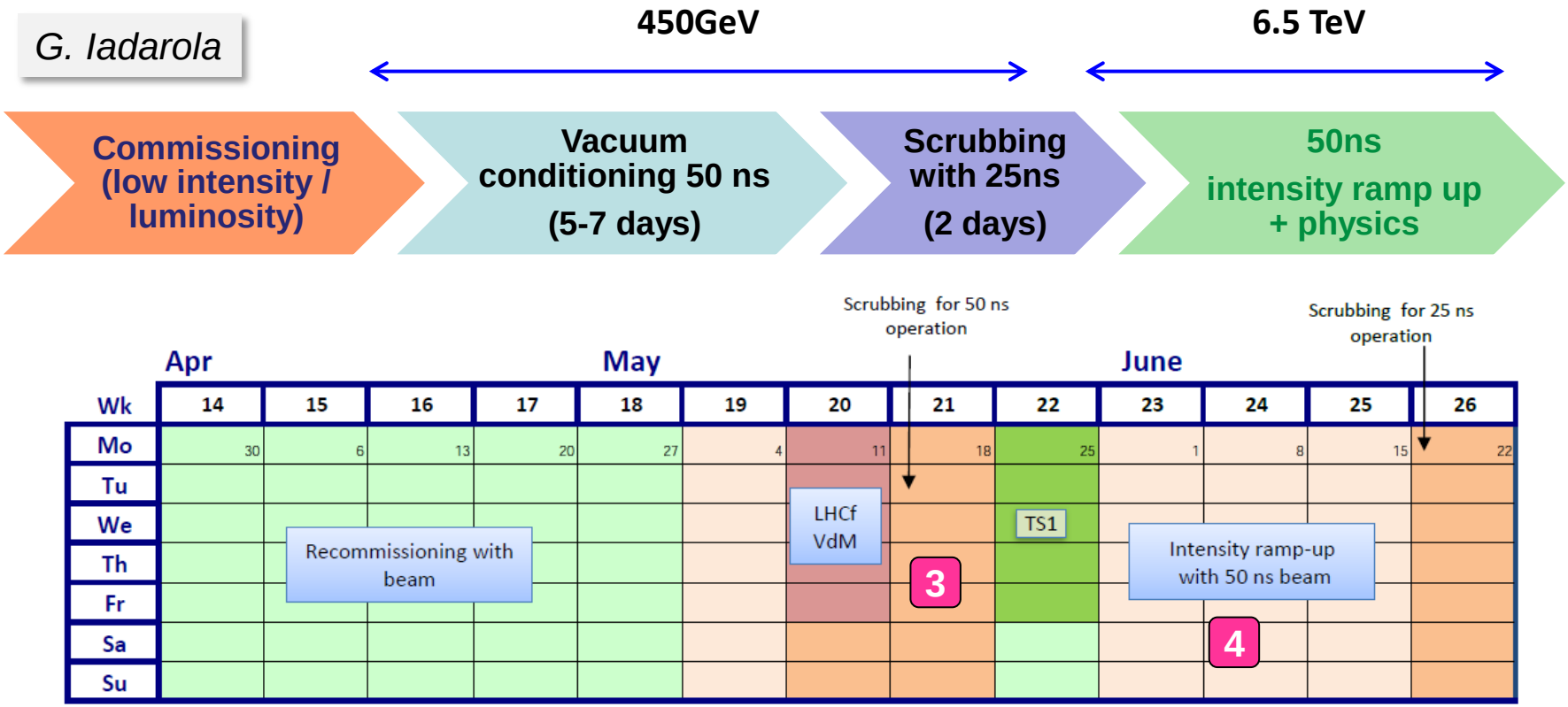
   Potentially with two β values*
7. Ion run



50 ns period strategy

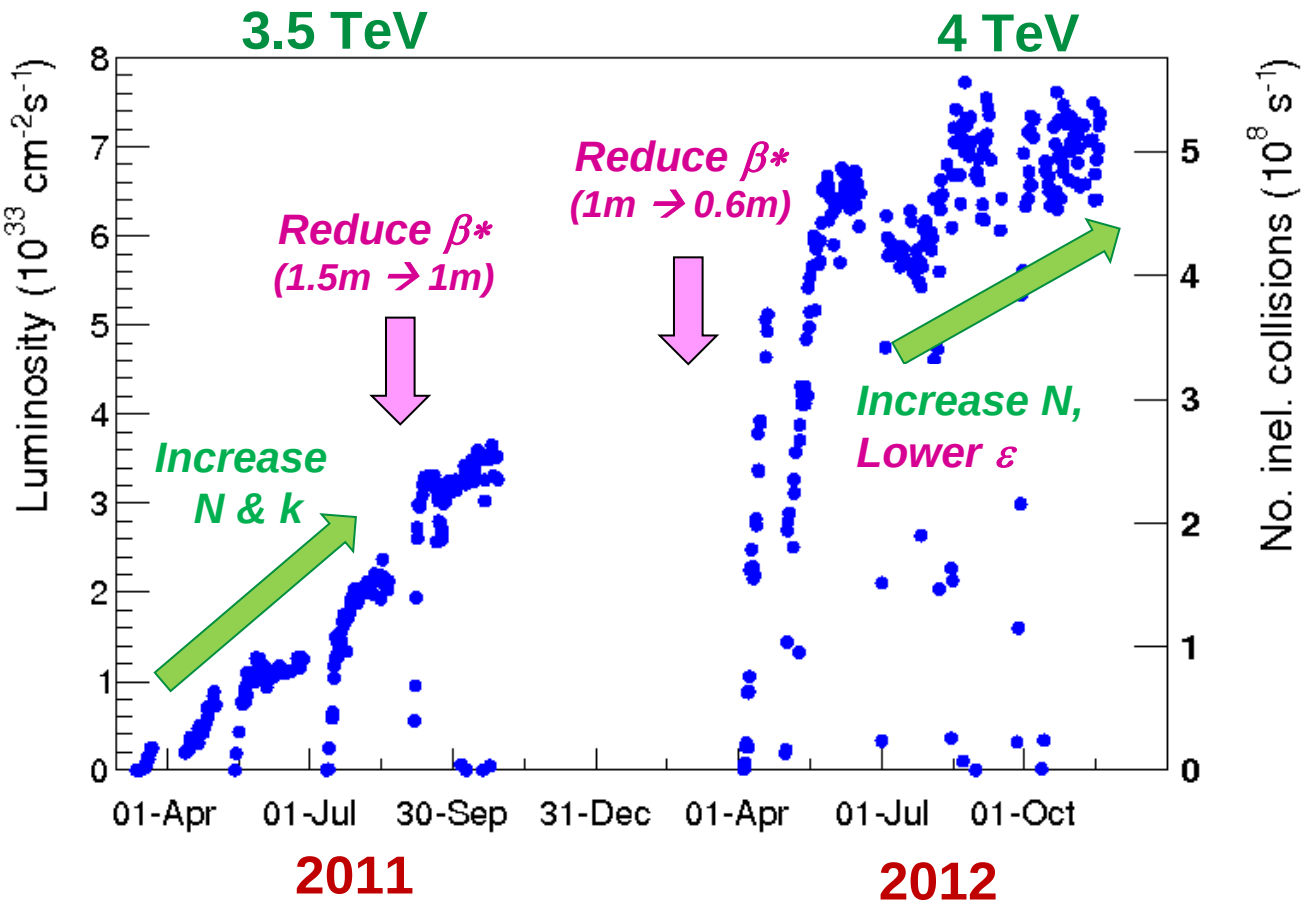
- The objective for the 50 ns phase is to *'reproduce' 2012-like performance @ 6.5 TeV* – with reduced e-clouds.
- This phase begins with a scrubbing run – initially with 50 ns and later with 25 ns beams – a well established scenario from run 1.
- The scrubbing is followed by 21 days of intensity ramp up.

G. Iadarola



50 ns ramp up in run 1

- **2011** intensity ramp up took ~9 effective weeks – **11** intensity steps – rate dictated by non-MPP issues from ~600 bunches.
  - *Losses & BLM thresholds, heating, beam stability etc.*
- **2012** intensity ramp up took 2 weeks – **7** intensity steps.



Intensity steps were defined by (r)MPP

50 ns in 2015

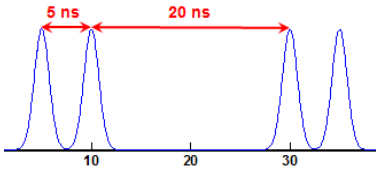
- The scheduled 3 weeks seem a bit short to reach 1380 bunches.
  - *Preliminary ramp up scenario (pending decision by rMPP) – 9 steps :*
    - 50 100 250 500 760 900 1100 1240 1380 bunches
  - *One step every ~3 days (⇔ no issues).*
    - MP checklists

See presentation by B . Salvachua

- If we do not encounter show stoppers, we should be able to hit the ~1000b regime which is a reasonable target.
  - *No(t too much) e-cloud (photo-electrons),*
  - *UFOs will already strike – first feedback on BLM thresholds?*
  - *First heating checks.*
- The current plan is to stick to similar bunch intensities than for 25 ns beams (~1.2×10^{11}).
  - *Pushing the bunch pop. toward 1.5×10^{11} may be used to probe the beam stability (also later as test during 25 ns phase).*

25 ns period strategy

- The central issue for 25 ns is evidently scrubbing & e-cloud.
- The December 2012 experience indicates that we may have to change the strategy and introduce a more powerful scrubbing beam – the 5-20 ns doublets.
  - *Duration and outcome are not as clear as for 50 ns case.*



G. Iadarola

450GeV ⟷ **6.5 TeV**

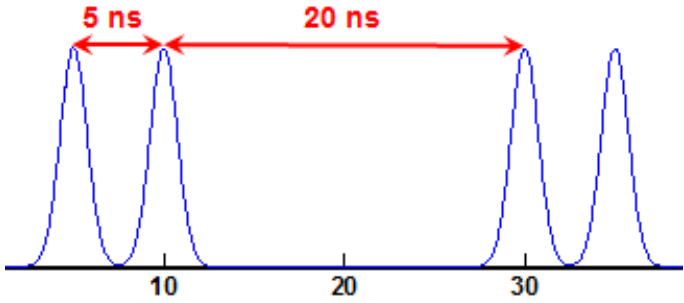
25 ns scrubbing (5 days) → **Scrubbing with doublet beams (5 days)** → **Scrubbing qualification 25 ns test ramps (5 days)**

Scrubbing for 25 ns operation

June				July				Aug					Sep			
23	24	25	26	Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
1	8	15	22	Mo	29	6	13	20	27	3	10	17	24	31	7	14	21
				Tu													
Intensity ramp-up with 50 ns beam			5	We	1	MD 1							TS2	SPECIAL RUNS (VdM, high beta etc.)	MD 2		
				Th	5			Intensity ramp-up with 25 ns beam		6							
				Fr													
				Sa											lower beta*		
				Su													

Doublet beam

- May be absolutely essential for scrubbing!!
- Requires adequate time for preparation:
  - *SPS: capture, slow ramp, extraction.*
  - *LHC: injection, capture, instrumentation.*
  - *Intensity per doublet → ≥1.6×10^{11} !!!*



- Most LHC instruments or systems will be able to *cope* with the doublets – in general averaging over the doublets – ≈ OK.
- Critical items on the LHC side:
  - *Interlock BPMs in IR6 (protection of dump channel) – systematic orbit shifts requiring tighter interlocks → un-manageable configuration.*
  - *Very important tests at the SPS this year.*
- **It is essential to test the doublet beam (~12 doublets) as soon as possible during the early commissioning**.

Intensity ramp up

- During run1 we collided 400b / beam with 25 ns, and *'virtually'* managed 800b – almost 30% of the way (easier part !).
- Tentative 25 ns intensity ramp up in **11 steps** (to be discussed & approved by rMPP):
  - steps : 140 300 600 900 1200 1500 1750 2000 2300 2600 2800
  - Fine tuning for e-cloud.

See talks by B. Salvachua & G. Iadarola

- On the way we will hit UFOs, stability issues, heating etc we will have to be reactive and be ready to invest into tests & MDs.
- Slow scrubbing during physics operation is probably the most annoying scenario – 'endless' intensity ramping.
  - *With conditions ~ December 2014 we are limited to ~30-50% of the total intensity due to the heat load into the cryogenics system.*
  - *Special beams with low e-cloud (8b+4e) – 25 ns with many holes – are a safety net, but not a real solution (~1800b instead of >2500).*

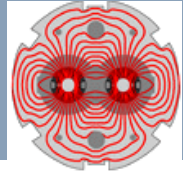
See talk by G. Iadarola

Pushing performance

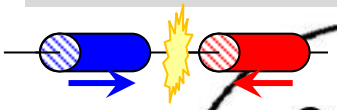
- In parallel to the 50 ns / 25 ns intensity ramping & operation periods we have to prepare the future – pushing to peak performance:
  - *ALARA β^*.*
  - *Beam brightness & stability.*
- The 2015 running period has only 3 MDs – one is before the 25 ns ramp up – and it is unlikely that we can fit all tests into them – see all presentation by J. Uythoven.
  - *We may need more distributed testing to be able iterate.*

  → Timing of MDs and β^* reduction period to be optimized?
- Studies must be performed in parallel to early 25 ns operation.
  - *This may set limits on achievable beam parameters – use 50 ns beam and alternate standard/BCMS beams for some tests.*

Snakes & ladders – favorite β* game



Collide & squeeze



MO polarity

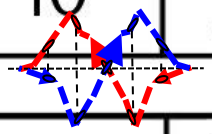
β* 40 cm

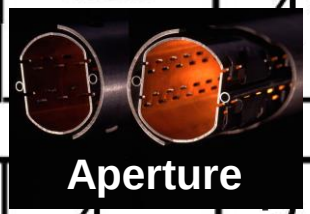
ADT

Collimator settings

Margins & stability

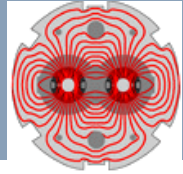
Beam-beam





β* 80 cm

Lower β* & stability studies



Non-exhaustive list of subjects for MDs and experiments → *J. Uythoven*

- *OP → 'parasitic' to regular physics operation (also commissioning phase).*
- *MD → dedicated time (out of MD or physics time).*

Subject		OP	MD
Optics	Squeeze to 40 cm (early commissioning), flat beams	Y	Y
Aperture	Detailed measurements – local triplet aperture	Y	N
Stability	Orbit at TCTs & triplets, collision point	Y	N
LRBB	Xing angle scans (bunch pop, emittance), interference with octupoles	N	Y
Collimator settings	Tighter settings, impact on impedance & stability	(Y)	Y
Octupoles	Sign and current, β* and LRBB interference, BCMS versus standard beams	(Y)	Y
Collide & Squeeze	Mechanics & reproducibility, β* leveling (plan B)	(Y) - N	Y
ADT	Gains, mode ('ideal' damper)	Y	Y

Priorities

- There is a large phase space for tuning, we have many players and significant time requirements.
- Stay focused:
  - Top priority: 2800 bunches with 25 ns @ 6.5 TeV.
  - Second priority: prioritize MDs and tests along a coherent line towards lower β^*.
    - Drawback of higher β^* → longer distance to the target.
- For changes that are introduced in // to operation, let's not change 3 things at the same time!

Towards lower β*

- **A step towards lower β* should be made in 2015 independently of a potential gain in integrated L !**
  - *Keep a margin of 3-4 weeks of operation after the change !*
- A step to β*~60 cm should be realizable from *MP & collimation perspective* as soon as we confirm:
  - *The aperture (early commissioning),*
  - *The orbit & optics reproducibility.*
    - With improved temperature stabilization of the BPM crates, we can hope for better reproducibility.
  - *Stability aspects to be checked…*
- A combined ramp & squeeze to ~3 m could be injected at this stage (if not done earlier) as a step towards higher efficiency.

Integrated luminosity estimates

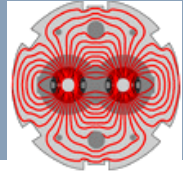
- Assuming ~35% availability.
- Intensity ramp up with 25 ns = 7 weeks = length first period.
- Uncertainties:
  - Length of operation period (β* step – when).
  - Value of β* step.
  - Beam parameters…

Period	N_{bunch} [10^{11}]	ε* [μm]	k	β* [cm]	L [$cm^{-2}s^{-1}$]	<μ>	Days(*)	∫L [fb^{-1}]
50 ns	1.2	2.2	≈1370	80	5.3×10^{33}	30	21	≈1
25 ns / 1	1.2	2.5	≈2500	80	8.1×10^{33}	26	44	≈4
25 ns / 2	1.2	2.5	≈2500	**40**	14.7×10^{33}	45	46	≈13

$\int L \approx 10\text{-}15\ fm^{-1}$

(*) no. of days of operation on the current schedule

Outline



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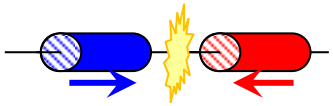
Collisions while squeezing / β* leveling



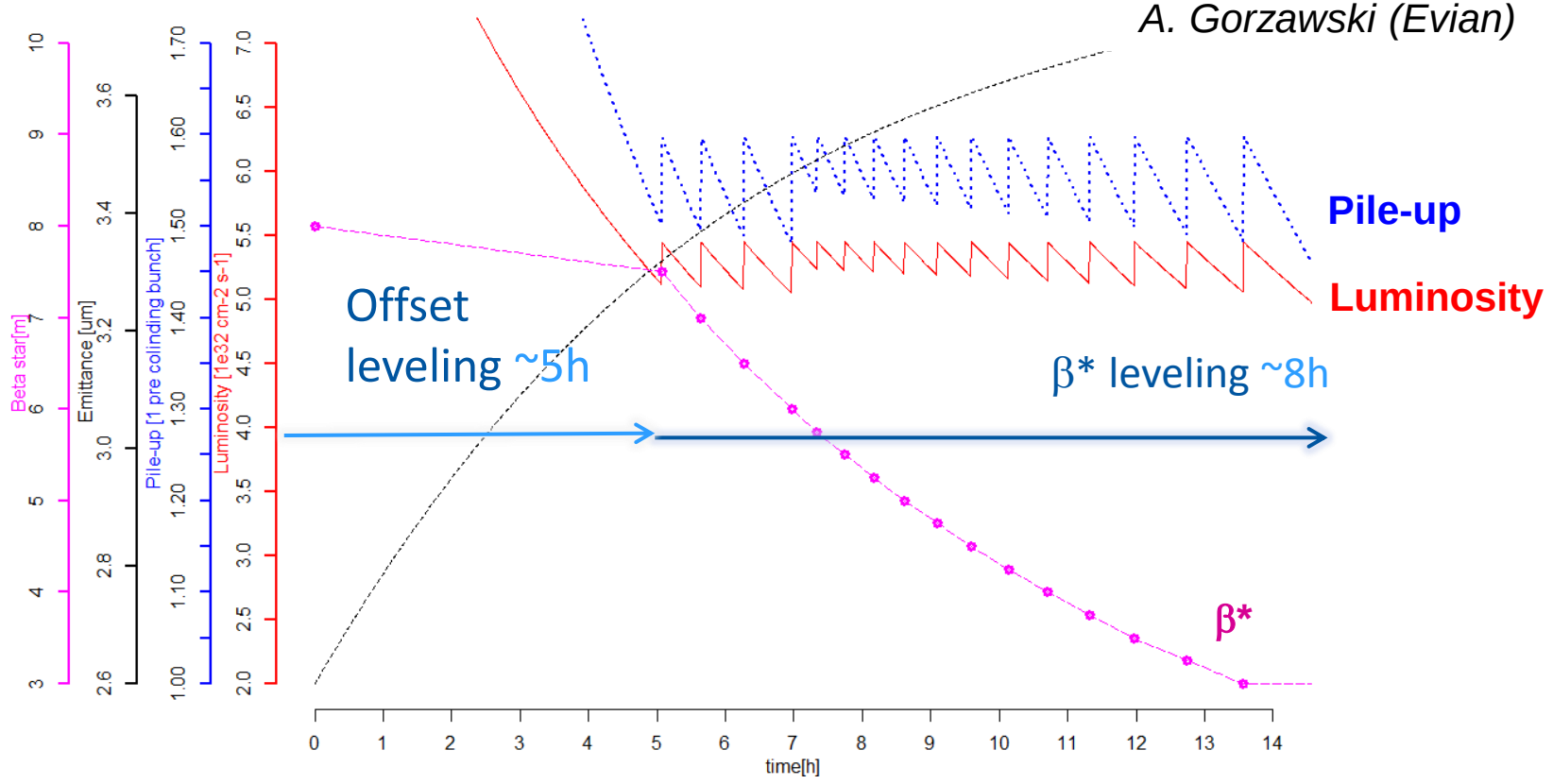
- We are squeezing high intensity beams.
- We are colliding high intensity beams.
- Collide & squeeze (or β* leveling) combines both features - the issue is to maintain collisions within 0.5-1σ while squeezing.
- There is an ongoing debate whether this is required or not (or when it is required).
  - *Stabilization by head-on BB seems undisputed.*
  - *Ideal combination of negative octupole polarity with collisions (E. Metral & al).*
  - *Luminosity leveling: offset versus β*.*

- β* leveling and collide & squeeze are 'the same thing', except:
  - *β* leveling is easier on one hand – small isolated β* steps – and more difficult on the other hand – in stable beams with experiments on.*

β* test proposal

- To gain operational experience with limited risk it was proposed to perform L leveling in IR8 – at least partially – with β* leveling.
  - *Can start below 10 m!*
- Not ideal in combination with β* changes during the run – setup time.

Example: β leveling from 8 m*
A. Gorzawski (Evian)



VdM luminosity calibration & LHCf

- The LHC luminosity (cross-section) calibration is performed in special fills with van de Meer scans (VdM).
  - *Larger (injection) β^* and emittance → pile-up, spot size diagnostics.*
- To maintain similar performance at 6.5 TeV VdM scans should be performed @ β^* of 20-40 m.
  - *A de-squeeze is required wrt injection β^* (10-11 m).*
- LHCf requested a special low intensity run at β^* ~7-20 m during the first days of operation (radiation damage).
- Since both LHCf (radiation) and vdM scans (initial calibration) must be schedule in the first week(s) of operation:

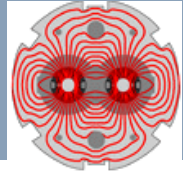
  $\Rightarrow$ combine LHCf & vdM setups to avoid one extra setup.

  (VdM scans in all IRs (but IR1) in // to LHCf run)
- Two setups (low & medium β^*) must be prepared during initial commissioning.

High beta - 90 m - run

- The high intensity 90 m run foreseen for 2014 requires a significant setup time, followed by an intensity ramp up.
  - ~1000 near-nominal bunches, spacing ≥ 75 ns.
- Preparation assuming that standard injection and ramp are re-used:
  - *Low intensity commissioning of the de-squeeze (flat machine) including optics measurements and corrections,*
    - Preferably done in advance.
  - *Collision setup & collimator (TCT) alignment,*
  - *MP validation and short intensity ramp up.*
- The estimated total commissioning time is ≈3 days.
  - *Similar in scale to the VdM setup and ion runs.*

Outline



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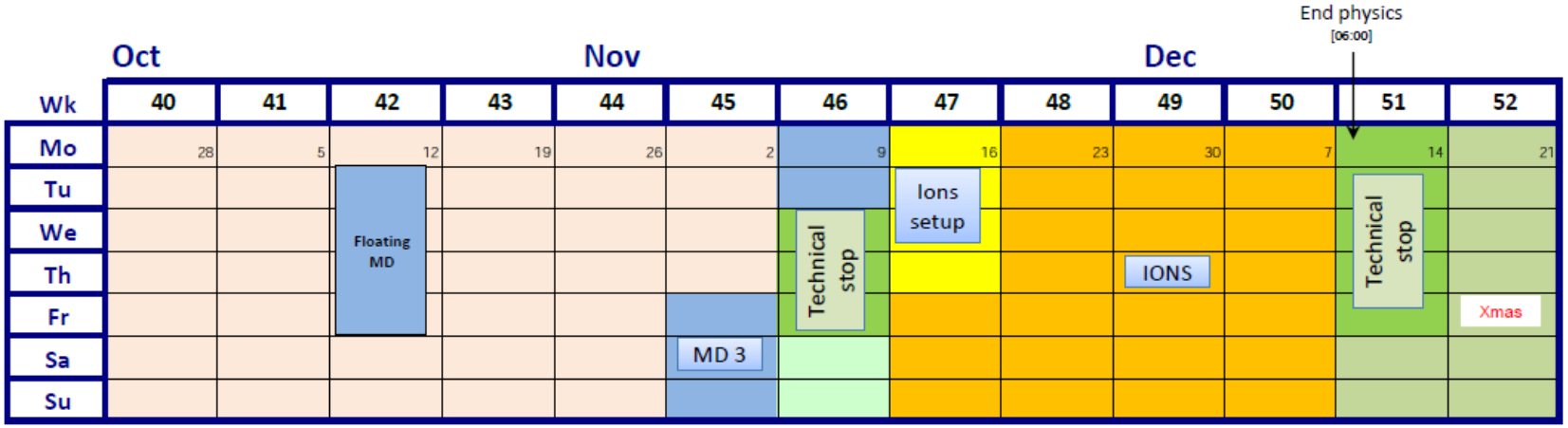
Ions

- The 2015 running periods end with the traditional ion (Pb-Pb) run.
- The preferred energy is **6.37 Z TeV** and not 6.5 Z TeV – from the p-Pb run at 4 Z TeV (equivalent CM energy/nucleon).
- No energy change is evidently always simpler !
- But the overhead of an energy change may be 'marginal':
  - *All MPS validations must be repeated with ions,*
  - *A new combined squeeze of IR1+IR5**+IR2** must be setup (preferred), bootstrapped with IR1+IR5 squeeze corrections (indep. of energy),*
  - *Only the ramp must be shortened and tested,*

→ *Acceptable overhead of ~ 1 shift ?*



Intermediate energy run

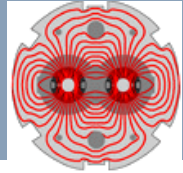
- An intermediate energy run at 2.56 TeV / beam will be requested for comparison with the Pb-Pb at 6.5 TeV (equiv. nucleon CM E).
- This run will be setup in a similar way than in 2013:
  - *Shortened ramp,*
  - *Injection β^* (10-11 m) – no squeeze,*
  - *25 (or 50) ns trains.*
- In 2013 the required setup time was ~2 days – it will be similar for 2.56 TeV.
- Performance (35% efficiency, 170 μrad ½ xing angle):

Period	N_{bunch} [10^{11}]	ε^* [μm]	k	β^* [m]	L [$cm^{-2}s^{-1}$]	∫L/day [pb^{-1}/d]
50 ns	1.2	2.5	≈1370	11	1.7×10^{32}	≈4
25 ns	1.1	2.5	≈2500	11	3.1×10^{32}	≈7

Summary

- The 2015 run presents us a fantastic mix of challenges.
- In parallel to learning how to operate at 6.5 TeV and with 25 ns beams we will have to prepare the future.
  - ***Remain focused on 25 ns !***
  - *MD periods are likely to be too short for a full program.*
  - ***Define an organized path to lower β^*.***
- Assuming that things move on reasonably, a reduction of β^* should be foreseen in the second 25 ns period based on the available information.
  - *Focus on future and not on immediate gains.*
- Ion run should be OK – energy to be decided (little impact).
  - *And do not forget associated low energy pp run at ~2.6 TeV.*

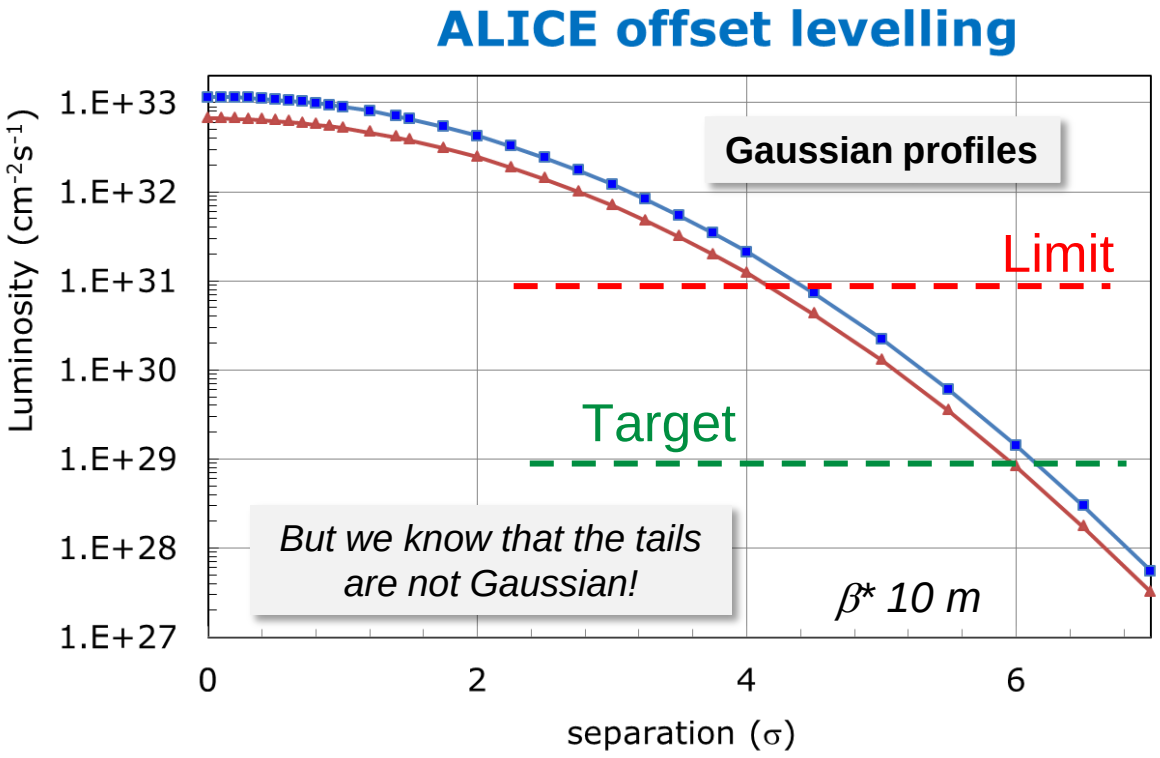
Stay tuned – and don't miss the 2015 run !



ALICE luminosity target

- The ALICE luminosity target for 2015 is very low ~10^{29} $cm^{-2}s^{-1}$.
  - Need extensive leveling by separation (β^* leveling not possible).
  - To avoid beam dumps due to excessive luminosity when colliding the beams we will aim for an initial separation of ~7-8σ.
  - Approach the beams step by step to target luminosity – std leveling.

Beam tail diagnostics with ALICE?



Intensity ramp up

Date	Fill	No. bunches	Beam
18.03	1634	32	75 ns
19.03	1637	64	
20.03	1640	136	
22.03	1645	200	
13.04	1704	228	50 ns
16.04	1716	336	
21.04	1728	480	
27.04	1743	624	
19.05	1795	768	
21.05	1799	912	
29.05	1815	1092	
21.06	1889	1236	
28.06	1901	1380	
07.10	2186	60	25 ns

2011

Date	Fill	No. bunches	Beam
05.04	2470	47	50 ns
05.04	2472	84	
06.04	2482	264	
08.04	2491	624	
12.04	2508	840	
13.04	2511	1092	
18.04	2533	1380	
15.12	3442	204	25 ns

2012

2013 proposal:

50 ns – 9 steps : 50 100 250 500 760 900 1100 1240 1380

25 ns – 11 steps : 140 300 600 900 1200 1500 1750 2000 2300 2600 2800

UFO

- Expect to start with an increased rate.
- Slow conditioning over 2-3 months.
- Situation at MKI should be largely improved.
- Situation in Arcs:
  - *Rate increases due to higher losses + lower quench thresholds,*
  - *Quench tests indicate that we have a margin on thresholds that could ~ compensate the rate increase,*
  - *BLM relocation (1/3) optimizes protection / thresholds.*